The DIAMOND Model of Peace Support Operations

Peter W. Bailey
Dstl Analysis
High Level Studies
Ively Road
Farnborough, Hampshire GU14 OLX
UNITED KINGDOM
+44 (0)1252 455304

pwbailey@dstl.gov.uk

ABSTRACT

DIAMOND (DIplomatic And Military Operations in a Non-warfighting Domain) is a high-level stochastic simulation developed at Dstl Analysis as a key centrepiece within the Peace Support Operations (PSO) 'modelling jigsaw'. It is designed to examine the utility of military force elements and equipments, the effectiveness of future force structures, and possible outcomes of different operational strategies within PSO. It represents the differing parties in a PSO, which may include military organisations, non-combatants, Non-Governmental Organisations (NGOs) and civilians, together with their relationships.

***Key Words**: Simulation, Peace Support Operations, Multi-sided.*

1.0 INTRODUCTION

1.1 Dstl Analysis

Dstl Analysis is the operational research (OR) arm of the Defence Science and Technology Laboratories (Dstl). Most Dstl Analysis study programmes support UK Ministry of Defence (MoD) planning processes on policy, procurement and operations. Conventional combat has in the past been the core study area for Dstl Analysis. To support this, a wide range of OR tools and techniques have been developed to support Dstl Analysis' study programmes. However, since the end of the Cold War, greater emphasis has been placed on understanding operations that fall outside of conventional combat. In recent years, the ever-increasing commitment of the UK's armed forces to Peace Support Operations (PSO) has exposed a shortfall in high level modelling tools suitable for analysis of non-warfighting military tasks. As a consequence of this shortfall Dstl Analysis is in the process of restructuring part of its tool-set to meet PSO OR requirements. DIAMOND (Diplomatic and Military Operations in a Non-warfighting Domain) is part of that programme.

1.2 The PSO Modelling Jigsaw

Modelling PSO is still a new and evolving area for the OR community. Rather understandably for such a young discipline there are many pieces to the 'jigsaw' but not yet the understanding of how they all fit together to provide the complete picture. In fact it could be argued that as a community we are still uncertain of which pieces we need to complete the jigsaw, let alone how they fit together. Figure 1 represents some aspects of this jigsaw and some of the pieces we have access to.

Paper presented at the RTO SAS Symposium on "Analysis of the Military Effectiveness of Future C2 Concepts and Systems", held at NC3A, The Hague, The Netherlands, 23-25 April 2002, and published in RTO-MP-117.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
00 DEC 2003	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
The DIAMOND Model of Peace Support Operations	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Dstl Analysis High Level Studies Ively Road Farnborough, Hampshire GU14 OLX UNITED KINGDOM**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001657., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**49**	

GAMING Pol-Mil gaming Computer assisted wargaming Tabletop wargaming	**SIMPLE ANALYSIS** Troops to task rules Concurrency modelling Military & expert judgement	**COMBAT MODELLING** Campaign level models Operational level models Tactical level models Logistics models C3I models
EXERCISES Computer assisted training Field exercises	**PSO HIGH LEVEL SIMULATION** **?**	**THEORY** Academic Institutions Lessons learnt Policy Doctrine
OPERATIONS UN operations NATO operations Africa Indonesia Balkans	**DATA** Geographical Demographic Environmental Equipment effectiveness Historical	**HUMAN BEHAVIOUR** Psychological modelling Sociological modelling Game theory Hyper & Meta games Power analysis

Figure 1: The PSO Modelling Jigsaw.

In answering any OR question on PSO it is important to examine the tools and techniques available to us and decide which of the pieces are most appropriate to answer that question. Some may be answered from a single source such as a database whereas others will require a combination of tools and techniques. Very complex questions, such as those concerning policy and force structures, require a wide selection of tools and sources and quickly become either too expensive to do or too complex to examine rapidly. One proven way to offset these disadvantages is to deploy simulation models that focus the data, techniques and understanding from other sources and provide an analytical environment in which to study complex questions. Figure 1 suggests that there is currently no tool available which fits the requirement for the high level simulation of PSO. DIAMOND, once completed and validated, will fill this requirement and provide a simulation model suitable to draw on the surrounding data, tools and techniques that we already have access to.

1.3 Requirement for DIAMOND

DIAMOND is under construction to address Force Development issues associated with peacekeeping, peace enforcement and humanitarian aid operations. Part of this requirement involves providing a tool to assist in answering the following types of question:

- Which force elements are essential to maintain the military mission?
- What is the utilisation of each force element[1] ?
- Are force elements used in their primary role or do they substitute for high demand elements?
- Are such substitutions efficient?
- How robust is the force mix option in adapting to changing political and military circumstances in theatre?

[1] Force element is defined as a company, battery or individual aircraft or ship.

- What is the ideal force mix to support an operation?
- What is the ideal force structure to support a wide variety of potentially concurrent operations?

One tool to answer these questions is a simulation model. In Figure 1, High Level Simulation (ergo DIAMOND) is shown at the centre of the puzzle. This is not to suggest that DIAMOND is the 'final piece' in the PSO jigsaw but to show that DIAMOND links into all the pieces that surround it. For high level force development work this is the logical arrangement of the pieces but for other studies, such as procurement or balance of investment, DIAMOND may sit on the periphery or provide no significant contribution to an OR solution at all.

It is also important to state that the current design for DIAMOND is not intended to provide a 'single model' solution for analysing policy and force development PSO issues. Although many aspects of the other tools and techniques can be incorporated directly into DIAMOND (e.g. data and doctrine) the model will still require indirect support from other areas. For example, DIAMOND may rely on other models or wargaming to develop an initial concept of operations and scope the political constraints for any given scenario.

For any study there will inevitably still be pieces of the jigsaw missing but as our understanding of PSO deepens those pieces will be discovered and introduced into the picture. As DIAMOND is an evolutionary development, the model will be continually improved to take into account our increased understanding of the domain and the model itself. DIAMOND has already highlighted some areas where we have either very little or no suitable data with which to examine particular aspects of PSO operations (e.g. refugee movements) and thus its development can be used to focus other work on collecting and assimilating information for study use.

1.4 Development Programme

The DIAMOND project began in August 1998 with a series of workshops to scope the requirement and focus the development on the core aspects of peacekeeping, peace enforcement and humanitarian aid. This resulted in the production of an outline requirement document establishing the aims and boundaries of the project. Following this a detailed requirement was written later that year as the foundation for all future work. A further eight months development effort followed and resulted in the production of the functional specification which outlined how the requirements would be implemented to produce the DIAMOND model. In September 1999 further workshops were convened to complete the design and begin the process of coding the model.

A working version of the model was delivered at the end of August 2000 with the model to be validated, commissioned and in use by April 2002. As the project is an evolutionary development it likely that further design and coding will occur after this date to build on lessons learnt and to incorporate research generated from the delivery of the first version of the model.

The validation exercise has examined a number of historical operations. These operations were chosen to meet specific aspects of the validation process as detailed in Figure 2. The intention of the validation exercise was to confirm that DIAMOND could be used to generate a feasible representation of the historical operations, it was not intended to calibrate the model to them. The reason for this is that the historical cases only represent one possible outcome and this outcome may not be the norm for operations of that type. The validation has concentrated on those areas of the model for which we have supporting data. There is also a parallel stream of work investigating other data sources, principally in those areas for which we have little or no prior experience of modelling (e.g. the humanitarian aspects such as food and water requirements and the effect of diseases). There will, of course, remain some data items that we cannot, currently, obtain supporting evidence for. It is believed, however, that the existence of DIAMOND will provide a focus (and rationale) for future data collection efforts.

Scenario	Validation Aspects
Bosnia IFOR, 1995 (Peace Keeping)	Test the boundaries of the model in terms of the size of scenario which can feasibly be represented and, more importantly, analysed
Mozambique, 2000 (Humanitarian Aid)	Test the humanitarian and engineering aspects
Sierra Leone, 2000 (Peace Enforcement / Evacuation)	Test the conflict and party interaction processes

Figure 2: Validation Scenarios.

The model was developed using the Rational Rose object-oriented modelling tool, Visual C++, Windows NT4, Microsoft Foundation Classes and DROMAS version 2.63.

2.0 TECHNICAL SPECIFICATION

2.1 Overview

DIAMOND is a fast running, high level, stochastic, object-oriented simulation of peacekeeping, peace enforcement and humanitarian aid operations (PSO). The major aspects of the technical design are summarised below.

A simple node and arc network provides a graphical representation of the region and environment allowing the model to represent key areas of interest, areas of sea or lake and the airspace above. Key facilities, such as airports and civilian shelter can be represented.

The model allows for the representation of key actors and contributors to PSO by use of Entities. These represent the capabilities and behaviours of military units, civilians, non-military organisations and the leaders or commanders for each. Entities interact with each other and the environment and exchange or consume key commodities such as food, fuel and ammunition.

The model incorporates a mechanism to organise entities into common ‘parties’ that represent specific organisations or common groups within a scenario. These parties have an appropriate command structure and communications network to facilitate the allocation of missions and flow of intelligence throughout the party. Parties have relationships with one another which define their interactions.

The model includes a mechanism to represent each party’s concept of operations by nesting objectives in a series of plans and for those objectives to consist of a series of missions that entities can prosecute during a campaign. Commanders within a party allocate resources to achieve their objectives in line with the sequence of plans and the simulation completes when a set number of parties achieve their end state conditions or when a predetermined period of time has elapsed.

During a model run entities gain information on their environment and other entities through sensing, interactions and communication. This information is organised into a local picture which allows those entities to make informed decisions on how they should prosecute their missions and activities delegated to them by their superior commanders.

Finally, DIAMOND includes a mechanism (referred to as negotiation) to obtain access to an area denied to one party by another and to allow multi-party co-operation to achieve aims and objectives without having to rely entirely on their own resources.

2.2 Environment & Facilities

A node and arc network provides the physical environment in DIAMOND. Nodes represent areas of operational interest, population centres and the locations of key infrastructure and terrain features. Arcs represent the routes between these nodes. An example Node – Arc network for DIAMOND is shown in Figure 3.

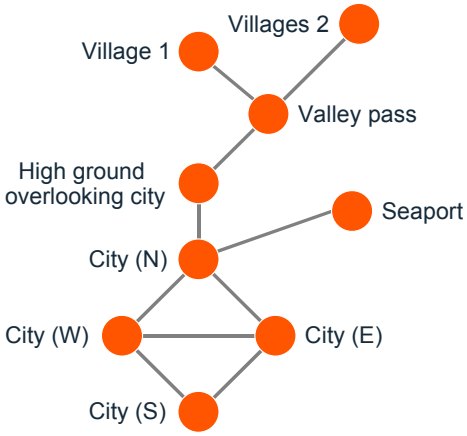


Figure 3: Example Node - Arc Network.

Nodes can, depending upon the nature of the scenario, represent whole cities such as London or individual districts or regions within a city such as Chelsea, Lambeth, Westminster or East and West London. They can be used to represent individual villages but it is proposed that a more appropriate aggregation level would be collections of villages. Nodes are also used to mark areas of deep water, points along an air corridor, strategic junctions and key terrain features.

Arcs represent the routes between the nodes and each one has several channels which can include ground routes (which aggregates the road, rail and cross country links), air corridors, inland waterways (canal, river, lake crossing aggregated), littoral waterways and deep waterways. The anticipated length of each arc is around 10 to 30km, although this can be much shorter where areas of interest are close to one another (e.g. the districts of a city).

The type of channel (and its capacity) determines which entities can move down that arc. For example, large ships cannot transit an arc connecting two water nodes with only an inland waterway channel (e.g. a canal), as they are prohibited from using any channel that is not a deep-sea waterway.

When defining the node/arc network (Net), the user must take care to ensure that the Net is established with a level of granularity appropriate to the entity size, i.e. division-sized entities on a Net where individual nodes represent single villages and settlements would be inappropriate. It is proposed that for an environment represented as cities, towns or districts with arcs between 10 to 30km then the appropriate entity size for military units is battlegroup, air package[2] and individual ship.

Nodes and Arcs both have a terrain type (called culture) which influences a variety of calculations such as the effectiveness of sensors, the rate of attrition between two units engaged in combat and movement rate. These culture types are: Urban, Suburban, Open Flat, Open Rolling, Open Mountainous, Scrub, Lightly wooded, Densely wooded, Mountainous and Open Water.

[2] Battlegroup: approximately 3 to 4 companies, Air package: approximately 1 to 4 aircraft.

Weather is also modelled and encapsulates factors with local, temporary effect. Weather on an arc defaults to the weather of the nearest node; ergo the midpoint of arcs is where weather types can change between different areas of interest. The weather condition at all points on the net is known by all entities. Advance forecasting of weather is not modelled in the first release of DIAMOND but may be introduced in later developments. Day and night is also not represented but, again, may be introduced in subsequent developments.

At each node it is possible for the user to define facilities, which are key attributes of that area that any entity can interact with. The facilities modelled in DIAMOND are: Shelter, Hospitals, Airports, Seaports, Targets. Each facility has the following generic attributes:

Damage points: The damage points for a facility indicate how hard it is to eliminate. Damage points are represented by two fields: the maximum damage points a facility can sustain before it is eliminated (or at least ceases being targetable by weapon systems) and its current damage points. Note: facilities may start a scenario already part damaged.

Capacity or Output: Most facilities produce an output or service of one type or another. For example, shelter has the capacity to house people; hospitals have the capacity to treat a number of patients per day. The capacity or output is different for each facility but the concept of capacity is generic across all facilities. The capacity can be degraded with damage. Therefore there are 2 fields: maximum capacity and current capacity. Both of these are dynamically calculated at the start and/or throughout a run.

Damage point to Capacity point conversion factors: As damage points inflicted affect the capacity of a facility the relationship between damage sustained and capacity is governed by the Damage point to Capacity point conversion factor.

Self-Repair capability and Self-Repair Threshold: Although engineering and construction entities in the simulation perform repairs, all facilities are likely to have an intrinsic self-repair capability based on the manpower and/or specialist equipment at the site. For example, civilians can repair light damage to their homes by boarding up windows, replacing missing tiles or through other makeshift repairs. Plumbers, builders and other specialists within the community could repair heavier damage and would not necessarily be represented by a special entity. These effects are represented by the Self-Repair capability, which is the number of damage points that facility may repair itself per day. Only when damage is very heavy and widespread do these local services become ineffective. As such, the self-repair capability of any facility will be limited and may cease to operate if the damage is heavy. This is represented by the Self-Repair Threshold, which is the number of damage points above which the Self-Repair capability is available.

Residual Capacity and Residual Threshold: Not all facilities can be totally destroyed and therefore even when fully damaged they may provide a residual capacity. For example, even if a hospital was destroyed some of the doctors could remain in the area and operate out of any acceptable premises. Consequently, a residual capacity is another general attribute of facilities. It is the minimum capability a facility can provide even if it has sustained maximum damage.

2.3 Entities & Activities

The entities in the model can be considered to fall broadly into the four categories below:

Intervention Forces: These are the Peacekeeping and Peace Enforcement forces with entities representing land, air, maritime and special forces units operating under a UN or other international mandate. Supplementary police forces to assist a failed state are also covered under this category.

Factions: The military and paramilitary forces of belligerent or warring factions who are not part of the peacekeeping or peace enforcement forces. The host nation's forces are also covered under the heading of factions. The entities include land, air, maritime and special forces units.

Non-military organisations (NMOs): NMOs include monitors and observers, commercial companies, governmental and international humanitarian agencies and non-governmental organisations.

Civilians: Civilians, including neutral civilians and those associated with individual factions, internally displaced persons, refugees and evacuees.

Each of these categories of actor can be represented in the model through use of an entity template. There are 5 types of template available. 3 are for different levels of commander, 1 for civilians and the other is a generic template used to describe all land, sea, air and NMO entities. In summary the templates are: Joint Theatre Commander, Component Commander, Intermediate Commander, Civilian Entity and Generic Entity.

Although 3 types of commander are specified it is implicit for both civilian and generic entities that they can command themselves if they have no direction from a superior. They have their own local picture and are capable of making decisions for their own survival and to achieve their missions. The higher level commanders allow for additional considerations, such as deciding which stage of a campaign plan should be followed, allocating resources to missions and directing a number of subordinate entities to work together to achieve a common goal.

Each template allows the user to define a number of key descriptors for that actor in the simulation: movement rate, size, sensor package, combat ability, transport capability, civilian/military identifier, commodity consumption rates, communications networks, engineering capability and the missions the entity is eligible to perform.

The proposed aggregation levels for land, air and maritime units in DIAMOND are battlegroup, package and single ship respectively. Civilian populations can vary between several hundred and several million and NMOs are likely to be small units of variable size and attributes.

As commanders represent headquarters, local government, individuals and in some cases the intangible collective actions of a set of common entities (e.g. refugees) their size is entirely user defined.

To allow the model to calculate 'entities to tasks' all entities, regardless of their size, are standardised in terms of 'components'. For military land units a component represents a deployable company or squadron and for maritime and air forces a component represents a single ship, boat or airframe. This choice was made to allow components for land units in DIAMOND to map directly from lower level combat models and for combat outcomes from those models to populate lookup tables in DIAMOND.

Although no detailed work has been done on what is an appropriate component level for NMOs it is proposed that a size of component comparable to their military counterparts be used in the first instance. Although this will mean some NMO entities will represent fractions of a component (e.g. a single land rover and two aid workers equals about 0.02 of a component), the entities to task rules can be written with this in mind and allow DIAMOND to substitute military and non-military entities between tasks (e.g. bridge repairs, food distribution).

2.4 Sensing & Communication

In DIAMOND, sensing & communication cover the processes by which entities directly acquire information about other entities, events and the environment. Sensing covers 3 processes: direct

observation, use of a sensor such as radar and experience of events such as interactions with other entities and the environment. The representation of sensors has been kept as simple as possible for the first release of DIAMOND. Rather than have explicit representation of known sensors such as radar, optics etc., the user is able to give names to generic sensor packages. A sensor package represents the collective sensor performance of that entity. For example, a British battlegroup can have numerous visual, IR and radar sensors plus the eyes and ears of over 500 soldiers. In DIAMOND this can be represented as a single sensor package. A unique name and the component types it is capable of detecting define each sensor package.

For the first release of DIAMOND 'cookie cutter' templates represent the range of sensors. The surrounding culture type of any target entity, the size of that entity and the local weather conditions modifies these ranges. Any item that falls within this adjusted maximum range of the sensor package will be detected and all entities that fall outside will evade detection. Different ranges within the cookie cutter determine the resolution (i.e. the detail) that the sensor information can provide (Figure 4).

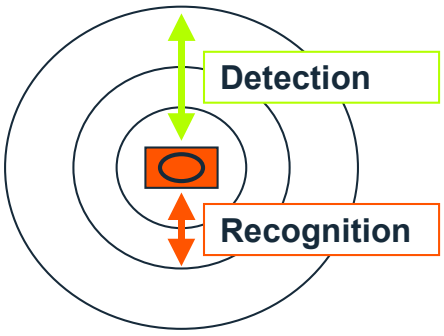


Figure 4: Representation of Sensors.

All information received by an entity (whether that be through sensing or communication) is assimilated into its local picture. The representation of local picture (and perceptions based upon it) is an important aspect of DIAMOND, as all entities decide what to do in the simulation on the basis of the information available to them. If this information is incomplete or out of date the entity's actions may be different, compared to their actions based on complete and current information. The local picture in DIAMOND is defined as the aggregation of all information made available to that entity with perfect and efficient data fusion. Perception is the translation from what that perfect picture looks like into what the entity 'believes' it knows. For the first release of DIAMOND local picture maps 1:1 onto perception. In subsequent developments the perception function may be enhanced to allow for misinterpretation, double plotting and extrapolation of information in the local picture.

Each piece of information recorded in the local picture consists of four items. They are: Unique identifier, Resolution, Credibility, Timestamp.

Unique Identifier: The unique identifier records the individual identity of every object in the simulation. This information is required by the model to ensure the same object is not plotted twice in the local picture. As the local picture is defined as the most efficient fusion of data the model will always plot the most useful combination of information relating to that unique object. This effect is not true for the perception picture where errors may occur (i.e. the object is plotted twice, it is plotted in the wrong place, it is mislabelled, it is mis-identified, or it is ignored). However, as previously stated, perception is not modelled to this level of detail for the first version of DIAMOND.

Resolution: The resolution class determines the detail of the information available about that entity. There are 5 levels of resolution, ranging from the least detailed, detection, through to the most detailed,

analysis. In DIAMOND as soon as a level of detail is acquired about another object it is time stamped against the unique ID of that entity and the specific information gathered at that level is recorded to a temporary store. That information can then be recalled whenever an entity consults their local picture about that specific piece of information.

Credibility: The credibility of the information (which is dependant upon the source of the information, previous credibility assigned to that information and the entity receiving the information) is also recorded. There are 5 levels of credibility in the model, ranging from certain through to incredible. Credibility influences whether entities use or discard that information when they make decisions based upon the information in their local picture. In the first version of DIAMOND the credibility may be detached from the other three data items (resolution class, timestamp and unique ID) to replace a lower credibility on a more accurate or up to date version of the same object (i.e. better resolution or timestamp).

Timestamp: It is important to timestamp when information is gathered because it is not instantaneously transmitted around a party's communications network. Hence this identifier ensures that only the most up-to-date information is recorded (not necessarily the most recently received). The model does not currently degrade information due to its age although this is a potential future enhancement.

Communications can be of four types:

Regular: Regular (or event triggered) communication between superiors and subordinates within a single party's communication network.

Direct: Communication between a commander and a subordinate entity from a different party who has been instructed to co-operate by its superior commander. This is a temporary (dynamic) link that will end when the mission they are co-operating on is complete.

Broadcast: A global broadcast that reaches all entities with a receive capability for that broadcast type.

Negotiation: Negotiation between two entities from different parties who are in the same 'peer group' (in the current implementation of DIAMOND only the highest-level commanders can negotiate). Examples include requests for escort, requests for supplies and requests for access. Negotiation is assumed to be supported by appropriate communications systems (e.g. radio if negotiating at distance, interpreters if negotiating face to face).

For communications DIAMOND represents a number of communications networks. Some nets (such as military networks) are party-based, while others (such as commercial news stations) are 'global'. Messages communicated include orders, status reports, requests for assistance, intelligence, local picture information and media broadcasts.

An entity will always communicate with its superiors and subordinates. The user can also create special nets to allow communications that do not follow the command structure. For example, these might include media, the 'rumour' network and face-to-face communication. On occasions this will occur dynamically is when an entity is assigned to operate for a commander (possibly in another party) that is not his direct superior. Under these circumstances the entity will report directly to its hierarchical commander and to the commander who has Operational Command (OPCOM) of that unit.

Broadcasts and directed messages are subject to delay at each level of command. Interoperability problems within a multinational force can be represented by additional delays in transferring information from one net to another when an entity has access to both. In DIAMOND entities from different parties may have 'receive' only links with other parties connected to the communications network to represent the sharing of intelligence.

2.5 Missions & Decision Making

The activities of entities within the environment are governed by 2 criteria. Firstly, the missions (i.e. tasks) represented in the model that entities are eligible to perform and secondly, the decision making processes in each party that determines how and when those missions should be prosecuted.

There are 12 missions in the model. They are: Transport, Intelligence, Move, Engineering, Defend, Reserve, Evacuate, Escort, Presence, Strike, Secure and Deny movement.

The majority of the missions cover general tasks that any entity in the simulation could undertake (Transport, Intelligence, Move, Engineering, Defend and Reserve). The other missions are those that are likely to be specific to either the peacekeeping forces (Evacuate, Escort, Presence and Strike) or to the belligerent factions (Secure and Deny movement). This is not to prevent the missions being interchangeable between the different parties within DIAMOND but to indicate that the design has focused on providing specific tasks associated with the principal actors involved in PSO. Each of the missions is interpreted by the entities that perform them as a series of activities. For example, the transport mission consists of the sequence: Plan, move, commodity exchange (i.e. load), move, commodity exchange (i.e. unload), reserve (i.e. become available for a new task) and communicate (i.e. report to superior commander that the entity is now available for new missions).

The missions themselves are organised into concurrent and sequential packages, referred to as plans. For example, a plan may include a mission to secure an area after which several transport and presence missions may occur concurrently. The entities undertaking the missions within the plan report at regular intervals whether they are succeeding or failing and their superiors may allocate additional resources (if they have them) to move failing missions back towards success. The relationship between plans, missions and activities is shown below in Figure 5.

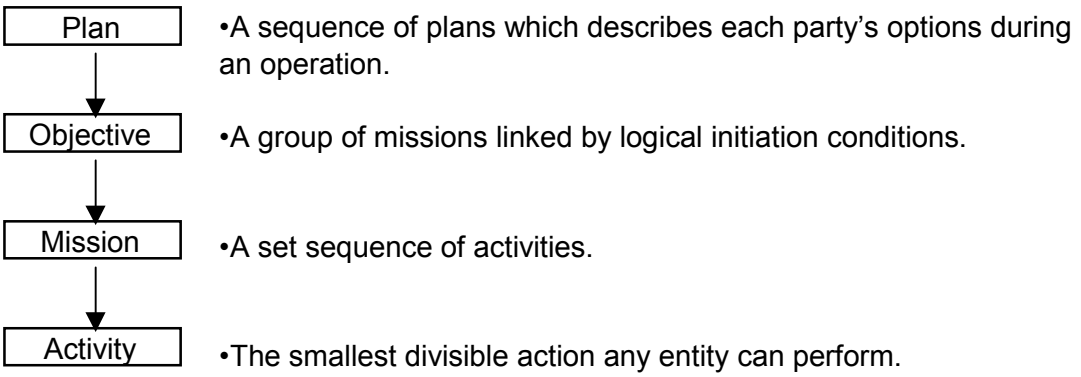


Figure 5: Relationship between Plans, Objectives, Missions and Activities.

Monitoring the overall progress of the plan is the Joint Theatre Commander (JTC) or his NMO equivalent. The JTC's perceptions include a function called the Campaign State Vector (CSV) and it is the CSV that indicates to the JTC whether the plan is succeeding or failing. Each plan has an associated set of initiation conditions and end conditions, which may be time dependent and/or success dependent. If a plan is failing (or has completed) the JTC will decide which is the next most appropriate plan to follow. This sequence of plans forms the party's Concept of Operations (Figure 6).

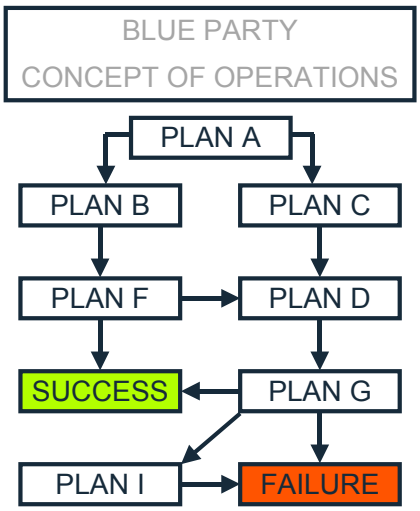


Figure 6: Example of a Party's Concept of Operations.

The 3 types of commander in DIAMOND make decisions associated with the progress of plans or missions. The levels of commander are the Joint Theatre Commander (JTC), the Component Commanders (CC) and the Intermediate Commanders (IC). There is technically a fourth level of commander, the entities themselves (military units, NMO's and civilians). This is shown diagrammatically in Figure 7.

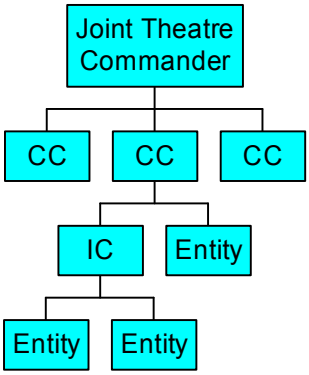


Figure 7: Command and Control Hierarchy.

The JTC controls the progress of the campaign by deciding which plan to follow at any time. Beneath the JTC sit the component commanders. The component commanders represent land, sea and air forces or could represent national contingents within a coalition. They 'size' each of the missions within a plan and delegate operational command to an appropriate intermediate commander in the party's hierarchy. For example, if the mission were suitable for a division then the responsibility for conducting the mission would be applied at the divisional level.

It is the intermediate commanders that represent this command chain with multiple levels representing (for example) battalion commanders up to corps commanders. They act upon the reports of their subordinates and manage their assigned mission as best they can. Should additional resources be required beyond what the IC can provide then they need to be requested from a superior.

Below the intermediate commanders are the entities themselves. Their command attributes are limited to prosecuting the activities that make up a mission and taking local decisions to enhance their survival or chances of success.

It is the combination of all these processes that allows the simulation to run without user assistance once a scenario has been scoped and developed. It is the development and testing of plans and mission sequences that requires the greatest input from the user. The majority of the processes related to sizing of missions and managing resources will be based on doctrine or operational experience.

2.6 Relationships

In existing combat models it has been traditional to represent only 2 sides of any conflict. This is a suitable assumption for most conventional battles as, regardless of the number of participants, they tend to fall into the categories of friend or foe. In non-warfighting operations this assumption is not valid, as there are often a large number of participants, none of which can be classified purely as hostile to each other. For example, in Bosnia there were 3 main armed factions, their respective civilian populations and the peacekeeping forces. In Somalia there were upwards of 24 warlords vying for control, the embattled civilians, the multinational peacekeeping forces and United Nations personnel, all of which were of strategic importance to the operation at one time or another. Very quickly it becomes obvious that any successful attempt to model non-warfighting operations requires a multi-sided approach. It was decided that each side in the simulation would be identified as a separate party and that the relationships between those parties would be used to describe their affiliations, rather than aggregating like-minded parties into distinct sides.

In accepting that a multi-sided model is required it is necessary to identify the relationships that will be required to describe the affiliations of each party. Again, in traditional combat modelling only one type of relationship is modelled, that of hostility between parties. In non-warfighting models a greater range of relationships is required. Research at Dstl Analysis has determined the minimum number of relationships required to represent basic inter-party behaviour is 5: Hostile, Uncooperative, Neutral, Sympathetic (co-operative) and Friendly.

Every entity within a party must share that party's relationships. For example, if a party of peacekeepers were neutral to the party of belligerents then every entity and commander within the peacekeeping party must share that view and see themselves as neutral also.

It was further recognised that a relationship between two parties does not have to be symmetric. For example, an NMO (Non-Military Organisation) may consider its relationship with a belligerent faction as neutral whereas that faction may adopt an uncooperative or even hostile stance in return. In the first release of DIAMOND, for simplicity, a party will always know the stance of other parties towards them, even if it is an asymmetric relationship. This leads to the possible relationship pairings depicted in Figure 8. Those marked with an asterisk are probably unstable relationships and would decay quickly to another relationship on the list once interactions begin between the two parties. However, this dynamic change in relationships is not represented in the current implementation.

	Hostile	Uncooperative	Neutral	Sympathetic	Friendly
Hostile	◆	◆	◆	❋	❋
Uncooperative		◆	◆	◆	❋
Neutral			◆	◆	◆
Sympathetic				◆	◆
Friendly					◆

Figure 8: The 15 Possible Relationship Pairings.

2.7 Negotiation

There are, in PSO, many types of negotiation that occur through the life of any operation. Mediation to resolve local disputes, negotiation to obtain a cease-fire and negotiation to obtain access are just a few. The types of negotiation the model is able to handle are:

- Negotiation for access
- Negotiation for support
- Requests for humanitarian assistance
- Requests for escort
- Requests for supplies (including demands and theft)

Each type of negotiation plays an important role in restoring normality or ensuring that potentially escalatory situations are resolved with the minimum amount of force by either side. As such aspects are an important part of PSO it is important that DIAMOND represents some elements of these interactions and their outcomes.

However, from the analytical community there has been very little related work on representing negotiation in a manner that is suitable for fast running simulation models. Consequently, DIAMOND has taken a two-path approach to representing some of the aspects of negotiation. The first path is the use of historical analysis and the second is to provide a mechanism that will allow the user to enter into the model the insights from Political-Military (Pol-Mil) gaming so that they can be interpreted dynamically by the model.

These approaches will allow DIAMOND to become the first stage in an evolutionary process for modelling cross party negotiation in PSO. Should either or both techniques prove successful then further development will follow.

Due to the time and expense incurred in conducting historical analysis only negotiation for access is represented with this approach. Roadblocks and other routeblocks are a major hindrance to peacekeeping operations, preventing or delaying free movement of peacekeepers, aid agencies and civilian traffic alike. They occur for a variety of needs, some through a genuine military reason to secure an area, some as a revenue source (tax and theft) and some simply because the protagonists are bored and see it as a means to exert their authority and pass time (Goodwin, 1999).

It is intended to conduct historical analysis on negotiation for access to identify the principal factors that affect the outcome. It is believed that current relationship, force ratio, rules of engagement and a unit's current mission are some of those factors. The input data to DIAMOND will be configured to match the important factors and referenced against a historical model derived from historical analysis. The output from this will be the time taken for a unit to negotiate and the probability of it successfully obtaining access.

There are some limitations in adopting this approach. The historical analysis conducted may be very region or context specific and may not allow for a fully generic approach. However, by ensuring that the historical analysis conducted focuses on areas or situations representative of the likely PSO contingencies there will be value in the data obtained for study use if not directly for DIAMOND itself.

The other types of negotiation that can be represented in the model will rely upon Pol-Mil gaming or expert judgement to define the conditions on which such a negotiation may produce a result. In these cases the time taken to conclude any negotiations will be represented and the model will represent the effect of a successful negotiation. Negotiation is confined to the missions represented within the model. For example,

a party could request a transport mission or intelligence from another party but it could not negotiate a local cease fire in this version of DIAMOND (as there is no specific mission associated with cease-fires).

These other types of negotiation can be generically referred to as 'negotiation for co-operation', although that co-operation may in itself be as a result of a threat or other aggressive activity. The user defines whether co-operation on any mission could occur with another party for each possible relationship pairing and should co-operation be possible the analyst defines which missions they would co-operate on.

2.8 Combat

Combat is not intended to form a major part of any DIAMOND scenario. However as one of the main tasks of military forces in PSO in the provision of a secure environment there is always the potential for conflict. The representation of combat within the current implementation is mainly limited to its impact on ground forces, there is no representation of air-to-air or maritime engagements. This is not deemed to be a major limitation as the key focus of the majority of the scenarios that could be modelled in DIAMOND will be the land forces.

The basic combat process is similar to CLARION, the high-level land combat simulation used within Dstl Analysis. Unit strengths are measured using a static scoring method, BAMS (Balanced Analysis & Modelling System) and effectiveness data is based on the results of more detailed (lower-level) models. Combat is initiated when all of the following conditions are met:

- opposing units are either situated within the same node or within a user-defined distance along arcs
- at least one of these units is aware of the other (i.e. it is in its local picture)
- the force ratio is above the withdraw level of all units
- Rules of Engagement (ROE), and by implication the relationship between the opposing units, permit the engagement

After initiation combat continues until all the units on one side are defeated. If additional units join the combat then the situation is reassessed according to the same initiation criteria.

This basic combat process has been enhanced for DIAMOND to take account of the multi-sided nature of the model. This is achieved through the use of ROE. These also allow the representation of the deterrence or conflict prevention function of peacekeeping forces. ROE can be individually defined for every mission but the standard approach is to use a number of templates, each tailored toward specific mission types. These ROE are only known by the owning party – it does not know the ROE of other parties.

The ROE are defined by the relationship to other party and determine:

- can the unit open fire first or in response only
- who or what can be targeted e.g. civilian or military targets
- can the unit respond on behalf of a third party or facilities
- quantity of fire

The careful use of these ROE can allow the representation of situations unique to PSO:

- the interposition of a peacekeeping force between warring factions to stop conflict
- the deterrence effect of peacekeeping forces preventing conflict
- the provision of security to the civilian population

Figure 9 shows an example of how combat works within DIAMOND. The Red armoured units (") advance into the node attacking the civilians and industrial facilities (which would be represented as 'target' facilities in DIAMOND) that are there. They do not attack the medical facilities as their ROE do not permit them to do this. The relationship between the Red and Blue forces (the infantry units, !, based at the node) is such that normally they would not engage each other. However, the ROE for the Blue forces allow them to go the defence of the civilian population and hence start to attack the Red forces. As a result of this, the Red forces switch their attention to the Blue forces as they present the biggest threat. The combat will end when either of the forces withdraws. If it is the Blue force that withdraws then Red will switch back to attacking the civilians and industry.

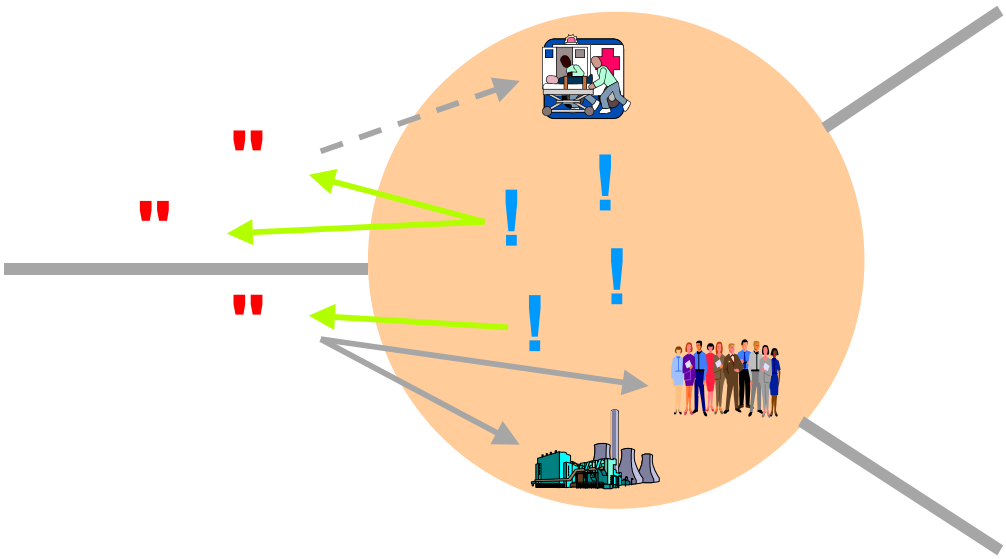


Figure 9: Example of Combat and the Impact of ROE.

The previous example could be modified such that the Red forces only attacked the industrial facilities. In this case, the ROE for Blue would not allow them to engage Red as the Red forces were not attacking civilians.

The example could also be modified to demonstrate the deterrence effect of a peacekeeping force. In this case the ROE for the Red forces could be set up to assume that Blue will attack Red, irrespective of Red's other actions. Conversely, as Blue is a peacekeeping force, its ROE are set up to only act in self-defence or on behalf of the civilian population. Hence the Red assumption is incorrect but it is unaware of this. In this case, if the combat power of the Blue forces is sufficient then no combat will occur at all. If the combat power of Blue is insufficient then combat will occur as Blue would then be in a position of having to defend itself.

3.0 CONCLUSIONS

In summary, DIAMOND has been designed specifically to tackle OR questions relating to high-level defence policy and force development issues. Once developed, validated and populated DIAMOND will allow the OR community to examine these areas economically and quickly and act as a focus for the application of other tools, techniques and data collection. Where possible the design has been kept firmly rooted in accepted and validated modelling techniques and driven by known data sources. However, to obtain as full a coverage of the PSO domain as possible it has been necessary to develop new techniques and mechanisms and cite the requirement for new classes of data or algorithms to be

developed. As our understanding of the PSO domain evolves so too will DIAMOND to take advantage of any new work and insights.

AUTHOR BIOGRAPHY

Peter W. Bailey is the Study Leader for the DIAMOND model at Dstl Analysis. Prior to taking up his current post, he was one of the analysts in the Operational Analysis Branch at HQ ARRC (Allied Command Europe Rapid Reaction Corps) and deployed with that HQ to Kosovo in June 1999.

DIAMOND

Diplomatic And Military Operations in a Non-warfighting Domain

Pete Bailey

Dstl Analysis

High Level Studies

Introduction

- Background
- Technical overview
- Future

Part 1: Background

Terminology

- Non-warfighting operations
- Operations Other Than War
- Other Operations
- Peace Support Operations (PSO)
- Crisis Response Operations
- Diplomatic & Military Operations
- Small Scale Contingencies
- Security And Stability Operations

Requirement for analysis of PSO

Increasing commitment of forces to PSOs

Dstl is required to support executive decision makers in UK MoD with operational research

Dstl's existing toolset is focussed towards warfighting operations

Dstl is restructuring part of its toolset to meet PSO operational research needs

PSO Analysis Tools

Exercises

Gaming

Simple Analysis

Detailed Modelling

Operations

High Level Simulation

Combat Modelling

Theory

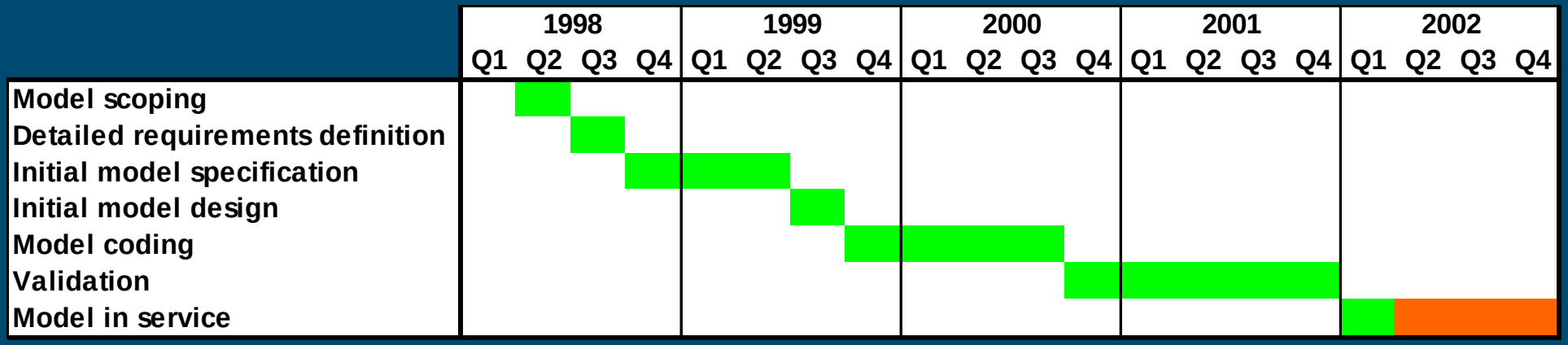
Data

Human Behaviour

High Level Simulation - Requirement

- Address issues associated with PSO at the theatre/campaign level
- Assess robustness of force structure against a variety of political/military environments encountered in PSO
  - Assess effectiveness of force mix
  - Assess impact of varying scales of effort
  - Assess utilisation of force elements
- Complement the CLARION and COMAND
- Potential feed into SABRINA

Development Programme



- Initial use of model in studies - Q2 2002
- Initial use will help to define future development needs

Part 2:
Technical overview

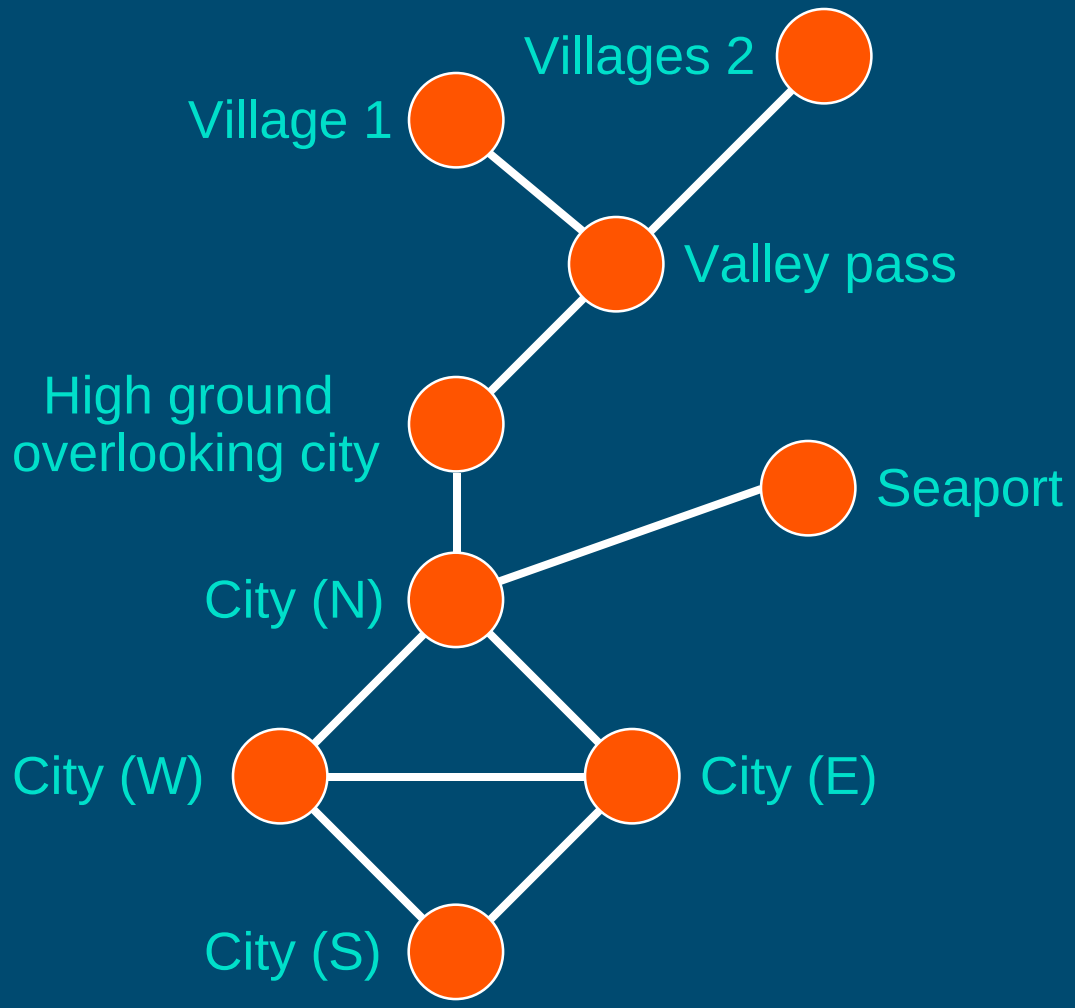
Overview

- DIAMOND is to be a fast running, stochastic model
- Represents
  - Theatre of Operations
  - C2 driven
  - Belligerent factions
  - Peacekeeping forces
- New Aspects
  - True multisided modelling
  - Civilians
  - Non-military organisations
  - Negotiation between parties (access & support)
  - Rules of Engagement

Environment & Facilities

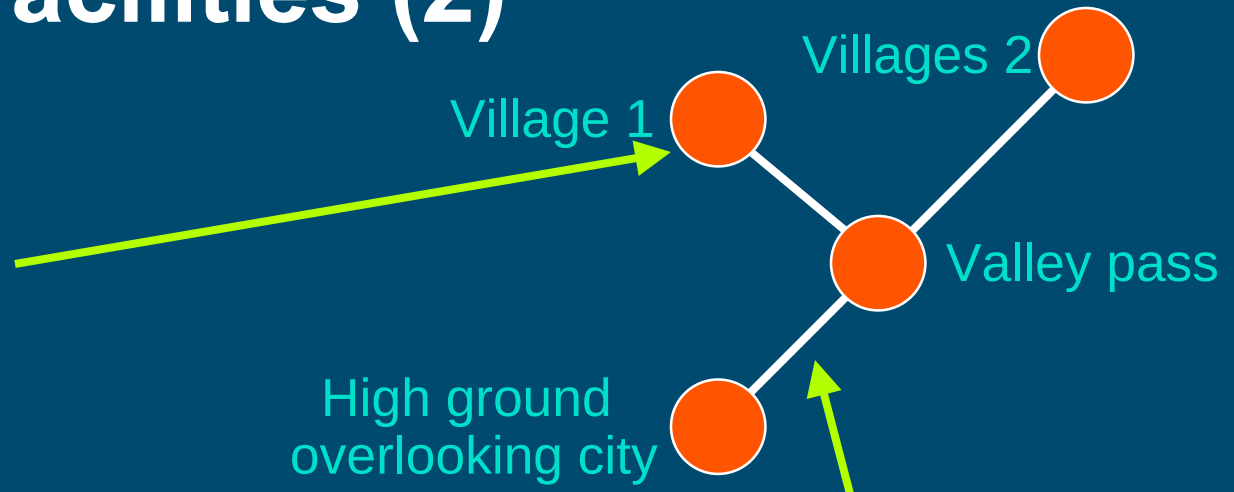
- Node and arc representation of theatre of operation

- Aggregation level (environment)
  - Nodes: Typically major population centres
  - Arcs: Typically 10 - 30km in length



Environment & Facilities (2)

Nodes
- Culture
- Area
- Fixed transit time
- Control marker
- Background law and order
- Facilities & commodity generation



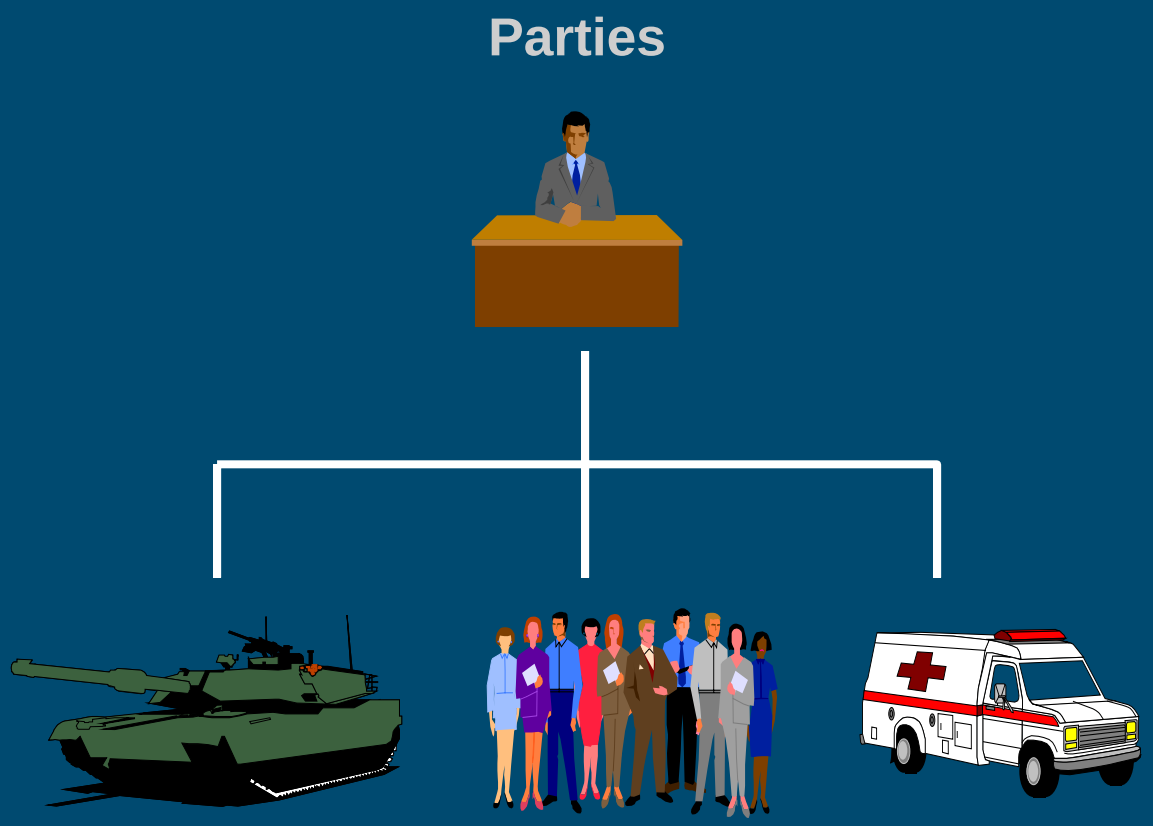
Facilities
- Shelter
- Water resources (on/off)
- Food production
- Hospitals (treatments per day)
- Seaport
- Airport
- 'Target' facilities

Node/arc interface facilities
- Bridges/Tunnels
- Route Delay
  - (mines/checkpoint)
  - (weather, route damage)

Arcs
- Culture
- Channels (e.g. ground)
- Length modifier
- Speed modifier
- Capacity

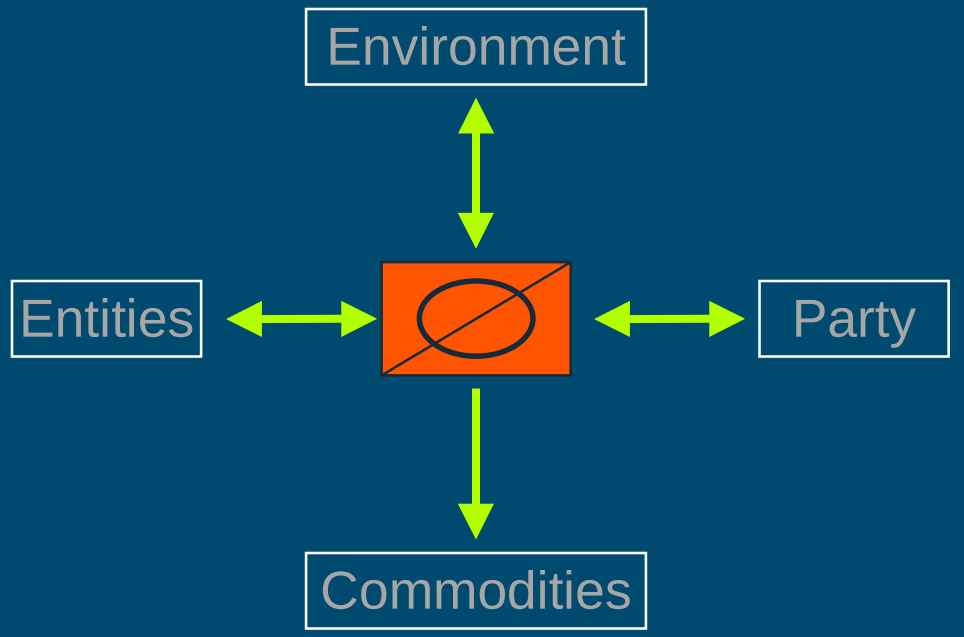
Entities

- Entities (Templates)
  - Commander (3 types)
  - Generic (military/NMO etc.)
  - Civilian (refugees etc.)
- Aggregation level (military)
  - platoon to battalion
  - Packages of 1 to 4 aircraft
  - Single ship
- Aggregation level (other)
  - NMO always variable
  - Civilian (100’s to millions)



Entity Activities

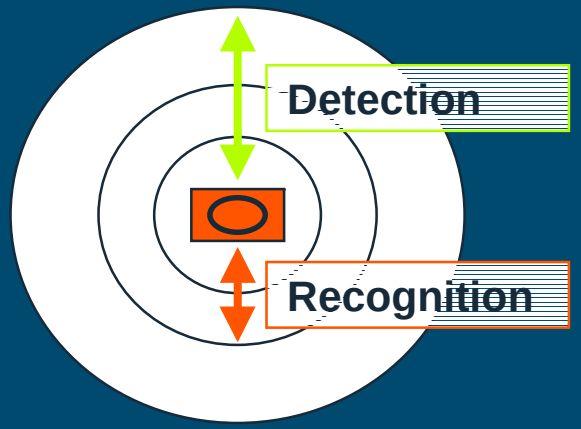
- The Activities are:
  - Plan
  - Communicate/Negotiate
  - Sense
  - Move
  - Damage/Repair
  - Block Route
  - Wait (Reserve)
  - Combat
  - Presence
  - Consume commodities
  - Commodity exchange



Entities consist of
- An appropriate decision making profile
- Sensor size (undetectable to large)
- Civilian/military identifier (for ROE)
- *Logistic capability*
- *Engineering capability*
- *Sensor capability*
- *Strike capability*

Sensing & Communication

- Entities gain information from
  - Communication
  - Sensors
  - Interactions
- All information consists of
  - Resolution
  - Credibility
  - Timestamp
- All information organised into Local Pictures



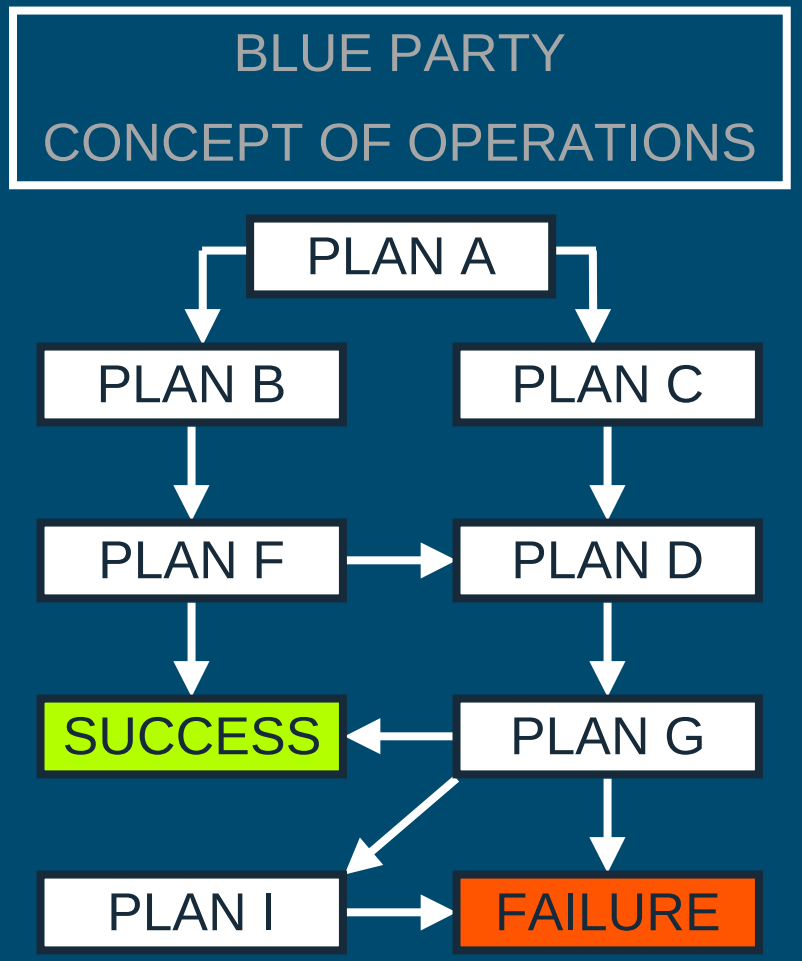
Local Picture
- Covers area of interest
- Entities (last known information)
- Environment (ground truth)
- Maps 1:1 onto perception

Sensing & Communication (2)

- Information Resolution
  - Detection
  - Status Recognition
  - Entity Recognition
  - Identification
  - Analysis
- Information Credibility
  - Incredible
  - Uncertain
  - Possible
  - Probable
  - Certain

Missions & Decision Making

- All parties begin with a series of nested PLANS
  - Plans are controlled by the perception of joint theatre commander
- Plans consist of sequences of OBJECTIVES which are based on a series of MISSIONS and mission areas
- There are 12 mission templates
- A mission is a set sequence of ACTIVITIES e.g. Transport
  - Plan, Move, Commodity Exchange, Move, Reserve, Communicate

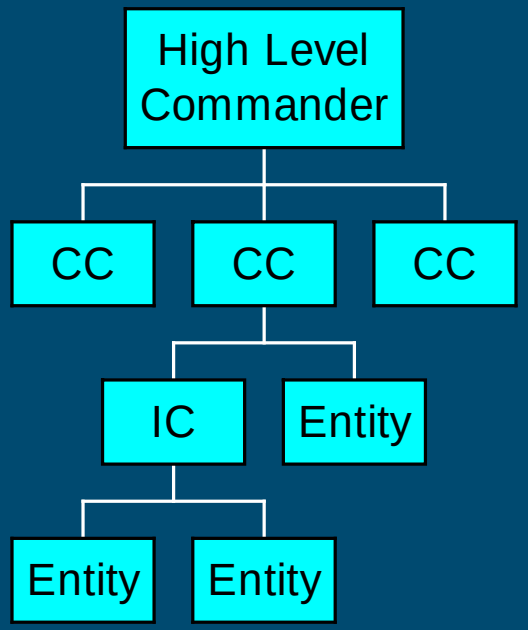


Missions & Decision Making (2)

- General missions
  - Transport
  - Evacuate
  - Intelligence
  - Move
  - Engineering
  - Reserve
- Peacekeeper / Belligerent missions
  - Escort
  - Presence
  - Defend
  - Deny movement
  - Secure
  - Strike

Commanders and C2

- High Level Commander
  - Campaign progress
- 'Component Commander' (CC)
  - Allocation of missions and resources
- Intermediate Commander (IC)
  - Operational Command of individual missions
- Entities
  - Prosecution of missions

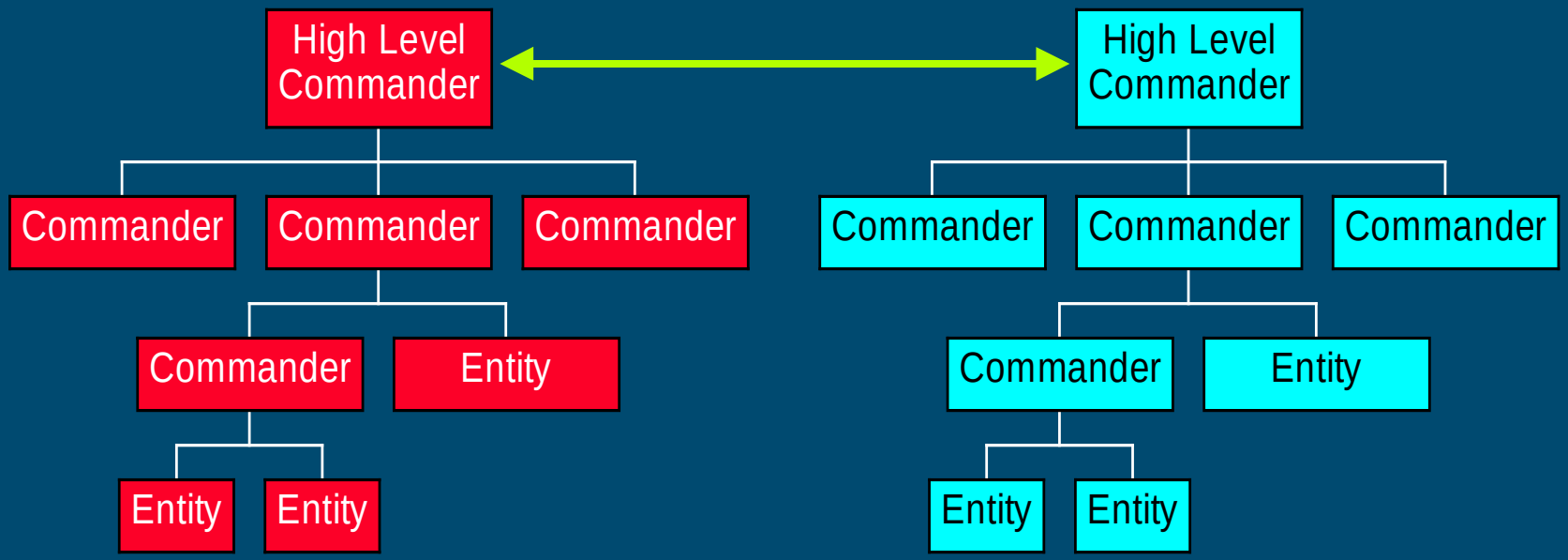


Relationships & Negotiation (1)

- Concept of relationships essential for multisided modelling
- 5 basic relationships
  - Friendly
  - Co-operative
  - Neutral
  - Uncooperative
  - Hostile
- Allows co-operative (and uncooperative) behaviour, not just conflict and indifference

Relationships & Negotiation (2)

- Two Negotiation types
  - Negotiation for access
  - Negotiation for support

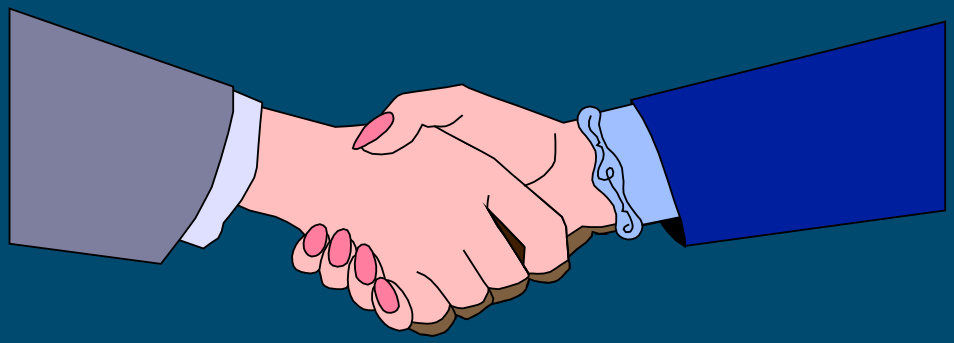


Relationships & Negotiation (3)

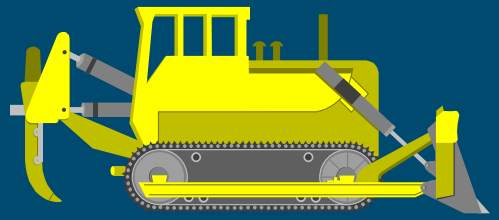
Negotiation for Support

- Support limited to the 12 missions types
- Access to resources (Food/Fuel/Ammo)
- Yes/No result depends on Relationship
- Cross party comms delays

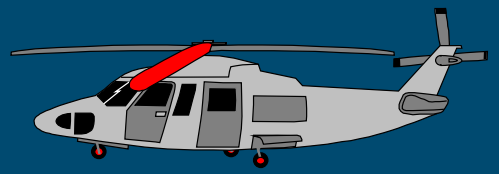
- *(Requires expert judgement to scope support matrix)*



Intelligence



Engineering



Transport

Combat (1)

- Impact limited mainly to ground forces
  - Currently no air-to-air or ship-to-ship engagements
- Effectiveness based upon lower level modelling
  - e.g. SIMBAT, air-to-ground and artillery studies
- Combat associated missions
  - Secure, Defend, Strike
  - Deny movement, Escort

Rules of Engagement

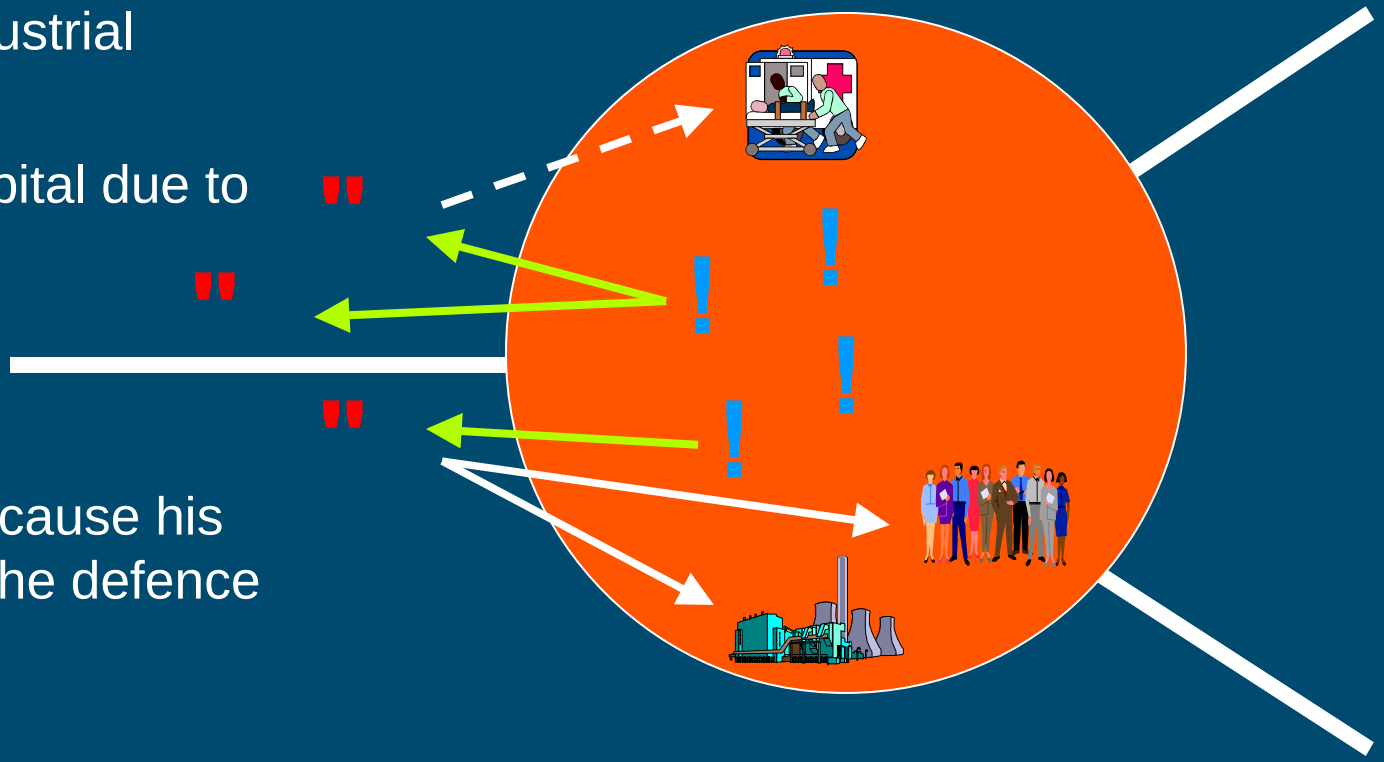
- Specific Rules of Engagement template for each mission
  - User defined
- Impact of ROE defined by
  - Relationship to other party
  - Open fire first? Or response only
  - Who or What can be targeted e.g. civilian or military targets
  - Response on behalf of third party or facilities
  - Quantity of fire

Combat (2)

- Unit strengths in Balanced Analysis & Modelling System (BAMS)
- Combat between entities depends on these key factors:
  - Combat initiation
    - Entity sensors
    - Rules of Engagement
    - Withdraw or stand force ratio
  - During combat
    - Unit effectiveness versus target type
    - Defeat level percentage
    - Minimum legitimate target strength

Example of ROE behaviour

- Red armoured units entering node engage civilians and industrial facilities
- Red cannot engage hospital due to their ROE constraints
- Blue will engage Red because his ROE allow him to go to the defence of civilian entities



Part 3:
Current & Future Work

Current Work

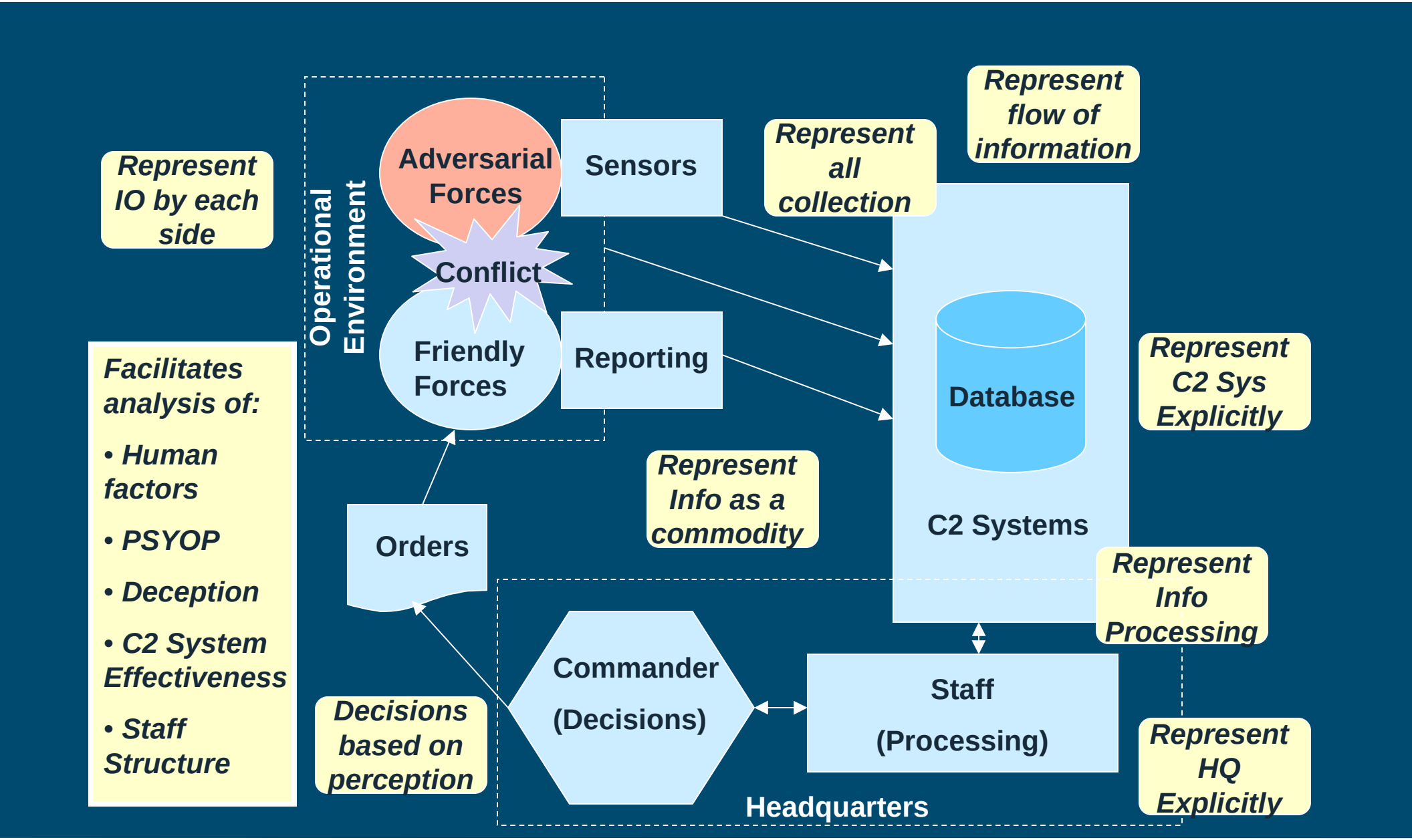
- 'Validation'
  - Bosnia IFOR (Dec 1995 - Nov 1996, Historical operation)
  - Sierra Leone (May - June 2000, Historical operation)
  - Mozambique (Feb - Mar 2000, Historical operation)
- Development
  - Resolve items arising from the validation
  - No addition of new functionality until completion of validation phase

International Collaboration

- Specification
  - David Davis, Col Jim Narel: George Mason University
- Briefing / Evaluation
  - ANN WG: NO - FFI, NL - TEL-FNO
  - TRAC Leavenworth (USA): Kent Pickett (AWARS)
  - DMSO (USA)
  - CAA (USA)
  - DSTO (Australia)
  - Symposia, Conferences: NATO SAS 027, Cornwallis, ISMOR

Way Forward

- Study use
  - Pilot study: Jan 2002
  - Release for study use: Apr 2002
- Expectation management
- Continuing development, including within international community


Represent IO by each side
Operational Environment
Adversarial Forces
Conflict
Friendly Forces
Sensors
Reporting
Represent all collection
Represent flow of information
Database
C2 Systems
Represent C2 Sys Explicitly
Represent Info as a commodity
Facilitates analysis of:
• Human factors
• PSYOP
• Deception
• C2 System Effectiveness
• Staff Structure
Orders
Represent Info Processing
Commander (Decisions)
Staff (Processing)
Decisions based on perception
Represent HQ Explicitly
Headquarters

Summary

- DIAMOND is a purpose built simulation of PSO that addresses
  - Dynamic and auditable assessment of PSOs for UK and coalition forces
  - Multisided scenarios with co-operative and uncooperative activities performed by a range of actors from civilians through to military forces
- Data collection
  - DIAMOND is already providing a framework for structuring data collection and processing
- Evolutionary approach
  - DIAMOND will evolve as our understanding of PSO improves

Questions?